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RESPIRATORY HEALTH DISORDERS AMONG WORKERS IN ASPHALT MIXING PLANTS

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Abstract

Introduction: Asphalt mixing plants' workers are exposed to different types of chemicals at the work place that may affect their respiratory system. **Aim of Work:** To study the respiratory health disorders among asphalt mixing plants' workers and to assess the workplace environment. **Materials and Methods:** A cross sectional study was conducted in 2 asphalt mixing plants, Menoufia Governorate and 100 asphalt mixing plants' workers have been included in the study during the period from the February 1st, 2020 to December 31th, 2021. An equal number of control subjects were chosen at random from workers' family members with the same socio-demographic characteristics and who had never been exposed to such risks. A predesigned questionnaire was used for interviewing all participants followed by physical examination and spirometric measurements. Assessment of the work environment was also done. **Results:** The average concentration of airborne particles was (3.872 0.307 mg/m3), which was higher than the Egyptian Environmental Law 4 Decree 1095, (2011) permitted threshold of (3 mg/m3). Furthermore, the total accumulation of crystalline silica in airborne particles was (45.58 2.531mg/m3), which was less than the acceptable amount established by Egyptian Environmental Law No. 4 Decree 1095, 2011 and Recommended Exposure Limit (REL) of NIOSH, 2005 for free crystalline silica level (50 µg/m3 = 0.05 mg/m3). Respiratory symptoms such as rhinitis, cough, productive cough, dyspnea, wheezes, and asthma were more common among workers exposed to free crystalline silica (60%, 62%, 35%, 67%, 31% and 24%; respectively), as well as spirometric measurements were statistically significantly lower compared to the controls ($p<0.05$). Significant negative correlation between work duration and FVC% and FEV1% were detected ($p \leq 0.05$). **Conclusion and Recommendations:** Working in asphalt mixing plants with exposure to free crystalline silica has been found to affect the respiratory system and induce decline in spirometric measurements. It's

recommended that personal protective equipment should be regularly used with proper ventilation of the workplace and continuous monitoring of the work environment to maintain the exposure levels below permissible values. Also, all workers should be subjected to periodic medical examination.

Keywords: Asphalt, Free crystalline silica, Spirometric measurements, Respiratory manifestations.

Introduction

Asphalt is a sticky, black and highly viscous liquid that represents the residuum that's produced from crude petroleum distillation under effect of reduced pressure, weather steam used or not (Singh et al., 2018). Mixture of bitumen with mineral matter (cement) is named asphalt-(Hasnain et al., 2019).

Asphalt aggregate, which includes crushed stone, sand, slag, gravel, and recycled concrete, is coarse to fine grained particle aggregate used in construction that are found to be source of respirable free crystalline silica that transported to workers' breathing zones by air currents near the milling machine (Hammonda et al., 2016).

Bitumen is a complex combination of polycyclic aromatic hydrocarbons (PAHs), heterocyclic chemicals, and some nitrogen, oxygen, and sulfur-containing molecules. These non-polar persistent chemical compounds have a significant potential for accumulating in living organisms (Aadil et al., 2019).

In asphalt mixing plants, the workplace environment is also, polluted with dust containing a proportion of respirable free crystalline silica. Respirable crystalline silica particles refer to those dust particles with aerodynamic diameter less than or equal to 10 micrometers that can penetrate upper respiratory system, and reach deep into the lungs and deposited in the alveoli and gas exchange membranes (Abdel Rasoul et al., 2017 [a] and Aldubayan et al., 2019)

Silicosis, lung cancer and tuberculosis are potential health effects following free crystalline silica exposure. Chronic obstructive pulmonary disease (COPD), kidney disease and connective tissue disorders are susceptible health problems among exposed workers (OSHA, 2002 and HSE, 2013). Silicosis is a work-related disease of the lungs caused by inhaling and reacting to free crystalline silica in airborne particles (CDC, 2010).

Exposure to high concentrations of bitumen fumes causes irritation of serous membrane of conjunctiva, nose, throat and lower respiratory tract.

Aim of Work

To study the respiratory health disorders among asphalt mixing plants' workers and to assess the workplace environment.

Materials and Methods

Study design: It is a cross sectional study.

Place and duration of the study: This study was carried out in two randomly chosen stationary asphalt mixing plants, Menoufia governorate, Egypt, during the period from the February 1st, 2020 to December 31th, 2021. The work is for one 8-hour shift / day for six days per week.

Study sample:

From a total of one hundred twenty nine (129) occupationally exposed male workers in the mixing department of the studied plants, only one hundred (100) workers were recruited in the study after exclusion of non-responders (11 workers) and application of exclusion criteria (18 workers). An unexposed group of one hundred (100) subjects were chosen randomly from workers relatives who were never been exposed to similar hazards. Both exposed and controls were matched regarding age, body mass index and smoking habits. Inclusion criteria**:** participants who had been employed at the asphalt mixing plants for more than a one year.

Exclusion criteria: workers with ongoing health problems including neurological, psychiatric, chronic respiratory, liver and kidney diseases or drug abuse.

Study methods:

An interview questionnaire was applied during the work shift at the work place which every setup took around 30 minutes and was done on a daily basis for eight personnels.

I- **A pre-designed questionnaire** was directly filled by all participants with interviewer's help: it includes: a) Personal data: name, age, residence (rural or urban), educational level (illiterate, primary and others), and special habits (e.g. smoking). b) Present occupational history (job nature, employment duration, daily working hours, worked days/week, availability and use of personal protective equipment, history of previous work, its nature, duration and extra jobs if present. c) Past history of respiratory symptoms, such as cough, rhinitis, wheezes, productive cough, breathlessness, chest pain, and asthma, which is defined as (chronic disease characterized by recurrent

attacks of breathlessness and wheezing, which vary in severity and frequency from person to another (ATS, 2013). d) Family history of: asthma, diabetes, and hypertension.

II- Clinical examination:

Clinical examination for each participant including weight (kg), height (cm), and calculating of body mass index "BMI= weight (kg)/ height (m^2)", vitals measurement including measurement of blood pressure (mm.Hg), the pulse (beats per minute) and body 's core temperature (°C), and local chest examination was performed.

III- Spirometric measurements:

The Smart Pulmonary Function Test Universal Serial Bus Spirometer from Medical Equipment Europe, PARI Medical Holding GmbH (Starnberg, Germany), was used to evaluate forced vital capacity (FVC%), forced expiratory volume at first second (FEV1%), forced expiratory ratio (FEV1/FVC%), forced expiratory flow during 25–75% of FVC ($FEF_{25–75\%}$), and peak expiratory flow % (PEF%). Three technically acceptable movements had their best values collected and displayed as percentages of projected values. It was possible to acquire an automated comment that signified understanding.

IV-Environmental studies:

Air samples were collected by using HETO Personal Dust Sampler throughout an 8-hour sampling interval, with flow rates ranging from 1.5 to 2 L/min. The cyclones were attached to the workers' clothing at the breathing zone, which is defined as the space between the outside of the shoulders and from the mid- chest to the top of the head. After collection, all samples were shipped to the analytical laboratory at Environmental Affairs Agency, Environmental Government (Gharbia Governorate, Tanta city) for analysis using spectrophotometric method measuring free crystalline silica level mainly.

Consent

All participants included in the study signed written informed consents before sharing into this study.

Ethical Approval

Before beginning, the protocol was authorized by the Medical Ethics Committee at Menoufia Faculty of Medicine.

Data Management

Using an IBM personal computer and IBM Statistical Package of So-

cial Science (SPSS) version 26, data was taken, tabulated, and statistical analyzed (SPSS Inc., Chicago, Illinois, USA). Shapiro-Wilk and Kolmogorov-Smirnov tests were used to check normality of quantitative data. For parametric data, student's t-test has been used and for non- parametric the Mann-Whitney test has been used, Chi-squared test (χ^2) was used to between two qualitative variables. In order to determine the relationship between two quantitative variables, the correlation coefficient (r) of Pearson was employed. A statistically significant p value of < 0.05 was used.

Results

Table (1): Environmental measurements of the studied asphalt mixing plants.

Studied variables	Measurements at work environment Mean ± SD	REL* of NIOSH, 2005	Permissible level of Egyptian Environmental Law, 2011
Total dust (mg/m^3)	7.162 ± 0.174	No REL	10
Respirable dust (mg/m^3)	3.872 ± 0.307	No REL	3
Silica (SiO_2) ($\mu g/m^3$):	45.58±2.531	50	50
CO (mg/m^3)	185.97±4.380	229	250
NO_2 (mg/m^3)	3.8 ±1.7	45	300
SO_2 ($\mu g/m^3$)	12.8 ±2.6	13	100

* REL: Recommended Exposure Limit

Table (1): showed that the mean concentration of respirable dust was higher than the recommended level set by Egyptian Environmental Law 4 Decree 1095, 2011 and that the measured accumulation of free crystalline silica was lower than the recommended levels set by Egyptian Environmental Law 4 Decree 1095, 2011 and the NIOSH, 2005 REL.

Table (2): Sociodemographic characteristics of the studied groups.

Sociodemographic characteristics	Exposed Group (No=100)		Controls (No=100)		Test of significance	p value
	No.	%	No.	%		
Age (years)**:** (Mean ± SD) Range	47.46 ± 8.97 28-59		46.01 ± 5.25 28-58		t =1.68	0.095
Income: Enough Not enough	68 32	68% 32%	78 22	78% 22%	$\chi^{2=}$2.536	0.111
Education: Illiterate and primary Others	60 40	60% 40%	48 52	48% 52%	$\chi^{2=}$2.899	0.089
Residence: Rural Urban	96 4	96% 4%	94 6	94% 6%	χ^2 =0.42	0.516
Smoking habit: Non smokers Smokers	43 57	43% 57%	52 48	52% 48%	χ^2=1.628	0.203
Smoking index: (Mean ± SD)	317.98 ±243.79		376.96 ± 178.23		U =1.79	0.073

U= Mann Whitney test χ2 = Chi- squared test t= t test

Table (2): showed that there was no statistically significant difference between the both studied groups regarding sociodemographic parameters and smoking habit and index.

Figure (1): Comparison between the studied groups regarding respiratory manifestations.

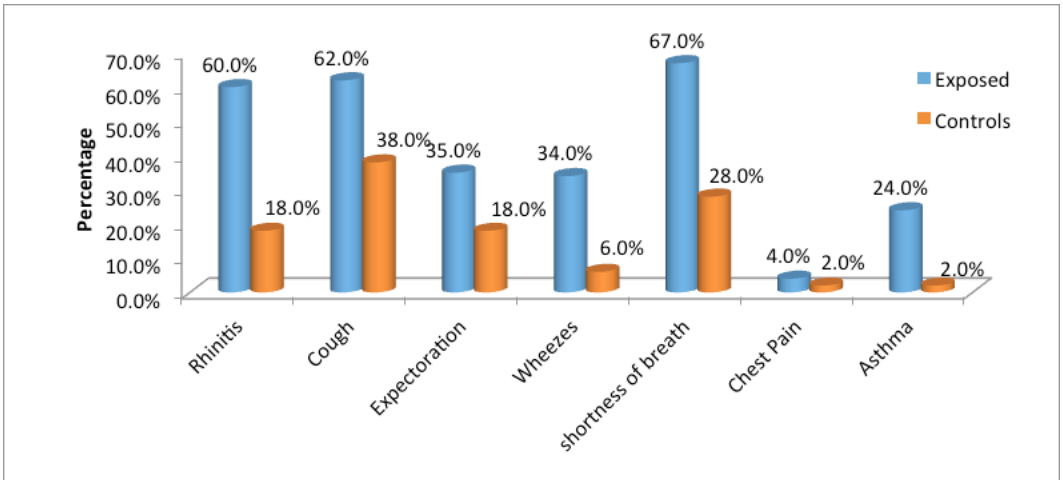

Fig. (1): showed that all respiratory symptoms were higher among the exposed group compared to the controls.

Table (3): Comparison between the studied groups regarding spirometric measurements:

Spirometric measurements	Studied groups		t – test	p value
	Exposed group (No=100) Mean ± SD	Controls (No =100) Mean ± SD		
FVC%	85.9±20.174	86.7±12.91	0.334	0.739
FEV_1%	76.65±20.258	87.02±15.027	4.111	**<0.001***
FEV_1/FVC%	90.43±21.066	101.44±17.361	4.032	**<0.001***
FEF_{25-75}%	81.58±20.225	97.60±58.004	0.409	**0.01***
PEF%	73.71±15.454	82.90±14.599	4.323	**<0.001***

*: Statistically significant

Table (3): showed that FEV1%, FEV1/FVC%, FEF25-75%, and PEF% were all statistically significantly lower among the exposed workers ($p<0.05$).

Table (4): Correlation between work duration (years) and spirometric measurements among the exposed group.

Spirometric measurements	Work duration /years		
	Correlation coefficient (r)	t	p value
FVC%	-0.244	2.49	**0.014***
FEV_1%	-0.325	3.402	**0.001***
FEV_1/FVC%	-0.176	1.769	0.08
FEF_{25-75}%	-0.101	1.004	0.621
PEF%	-0.050	0.495	0.315

*: Statistically significant

Table (4): showed a statistically significant negative correlation between work duration and both FVC% and FEV1% ($p < 0.05$).

Discussion

In Asphalt mixing plants, numerous health hazards exist including exposure to bitumen fumes and inhalation of airborne particulate matter from raw materials mainly free crystalline silica (CDC, 2000).

In the studied asphalt mixing plants in this work, environmental assessments revealed that the average total dust concentration was (7.162 ± 0.174 mg/m^3) and free crystalline silica in respirable dust level was (45.58 ± 2.531µg/m^3) (Table 1). These results were below the acceptable limit of the Egyptian Environmental Law No. 4 Decree 1095, 2011 and REL of NIOSH, 2005 (10 mg/m^3) and (50 µg/m^3 = 0.05 mg/m^3) respectively. Moreover, the average value of respirable dust (3.872 ± 0.307 mg/m^3) was greater than the allowed amount set by Environmental Law No. 4 Decree 1095, 2011 (3 mg/m^3) (Table 1).

Also environmental study of these plants revealed that the mean values of CO, NO_2 and SO_2 were (185.97 ± 4.380 mg/m^3, 3.8 ± 1.7 mg/m^3 and 12.8 ± 2.6 mg/m^3; respectively) (Table1). These results were lower than that reported by the Egyptian Environmental Law 4 Decree 1095, 2011 where the maximum limits of emissions of CO, NO_2 and SO_2 are 250 mg/m^3, 300 mg/m^3 and 100

mg/m^3; respectively and NIOSH, 2005 RELs which are 229 mg/m^3, 45 mg/m^3 and 13 mg/m^3; respectively (Table1).

These findings are consistent with the study done by Abdel Rasoul et al. (2013) Menoufia , Egypt; who recorded low levels of CO (243 ± 0.85 mg/m^3), NO_2 (244 ± 1.73 mg/m^3) and SO2 (31 ± 2.65 mg/m^3) in their study in a glass factory. Also, Abdel Rasoul et al. (2017[b]) recorded low level of CO (19.3 ± 3.5 mg/m^3), NO_2 (3.6 ± 1.7 mg/m^3) and SO_2 (12.9 ± 2.6 mg/m^3) in ceramic industry.

Respiratory symptoms such as rhinitis, cough, expectoration, dyspnea, wheezes, and asthma were shown to be considerably more common between asphalt mixing plant workers in the current study (60%, 62%, 35%, 67%, 31% and 24%; respectively) compared to the controls (18%, 38%, 18%, 28%, 6% and 2%; respectively) ($p < 0.05$) (Fig 1).These results could be attributed to the exposure to different respiratory hazards present in the work environment with a high level of total and respirable dust, poor ventilation and non-efficient personal protective equipment.

These findings were consistent with those of Neghab et al., (2015) in their cross-sectional study which was carried out to evaluate the respiratory effects of occupational exposure to asphalt fumes in paving workers of Shiraz, southern Iran and detected that respiratory symptoms such as (cough, phlegm, productive cough, wheezing, shortness of breath, and tightness of the chest) were substantially more common among asphalt mixing plant workers (30%, 28%, 27%, 31%, 22%, and 13%; respectively) compared to the control group (11%, 10%, 7%, 4%, 6% and 0%; respectively) ($p <0.05$).

On the other hand, Xu et al., (2018),in their study on exposure, respiratory symptoms, lung function and inflammation response of road-paving asphalt workers in Lund , Sweden; found no significant difference in newly developed upper or lower respiratory symptoms between asphalt working plants' workers and controls, this can be attributed to low level of exposure between their studied workers as median value of measured total dust and respirable dust in working environment were (0.18 mg/m^3 and 0.24 mg/m^3; respectively) .In addition, in their study; smoking was significantly higher between controls than asphalt mixing plants' workers that may affect their results.

When spirometric data were compared between asphalt mixing plant personnel and controls, the exposed workers had substantially lesser mean values of FEV1%, FEV1/FVC%, FEF25-75%, and PEF% (76.65 ± 20.258, 90.43 ± 21.066, 81.58 ± 20.225 and 73.71±15.454; respectively) compared to the controls (87.02 ± 15.027, 101.44 ± 17.361, 97.60 ± 58.004 and 82.90 ±14.599; respectively) (Table 3). FEV_1% mean values were (76.65 ± 20.258) which were lower than the American thoracic society (ATS), 2013 fifth percentile lower limit of normal which is 80% of predicted for FEV_1%. This indicates the adverse effect of exposure to free crystalline silica on ventilatory functions.

Ulvestad et al., (2016), who conducted research on male asphalt workers employed by one of Norway's leading road maintenance businesses, found similar results over 5 years, and reported significant lower mean values of both FVC% and FEV_1% between exposed workers compared to the controls and also an accelerated decline in both FVC% and FEV_1% between exposed workers during the 5-years follow-up.

In addition, Neghab et al., (2015) reported that exposure to asphalt fumes and free crystalline silica had a negative impact on FEV1/VC and FEV1/FVC% ratios with 20.3% decline in FEV1/FVC% among exposed compared to the controls**.**

The duration of exposure is an important determinant of diseases developed from respirable free crystalline silica, so particular attention was paid to correlate mean values of pulmonary function tests among workers with the work duration.

The effect of work duration in years was studied with spirometric measurements. On application of Pearson correlation, it was found that there was a statistically significant negative correlation between FVC% and FEV1% ($p<0.05$) and working duration /years. A non-significant negative correlation was also detected between working duration (years) and FEV1/FVC%, FEF25-75%, and PEF % ($p >0.05$) (Table 4).

The obstructive pattern in Spirograph may occur due to the presence of COPD and bronchial asthma. Restrictive pattern indicates the possibility of fibrosis in lung pathology (Bolund et al., 2018).

These findings support Ulvestad et al., (2017) findings of a quicker decrease in both FVC and FEV1 among asphalt

pavers in Oslo, Norway throughout a 5-years follow-up period when compared to the control group and the average yearly reduction in FVC and FEV1 was 58 and 35 ml, respectively between pavers. Therefore, they concluded that with increase duration of exposure; FEV_1, FVC% usually decreases.

Conclusion and Recommendations: Working in asphalt mixing plants with exposure to free crystalline silica and bitumen fumes has been found to affect the respiratory system and causing decline in spirometric measurements. We recommend continuous monitoring of work environment and keep levels of the respirable dust below the recommended levels with proper ventilation either natural or artificial. All workers should wear high-quality personal protective equipment and undergo regular medical examinations.

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Conflict of Interest

None declared

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